WDM Modul

Field of the invention

The present invention relates broadly to a WDM module. The present invention also relates to an optical network node and to an optical network and to a regenerator node for a WDM network.

Background of the invention

Optical networks may be classified into long haul optical networks, metro optical networks, access optical networks and enterprise gear-optical networks. Distinctions between the different types may in a first instance be drawn on the basis of physical transmission distances covered, decreasing from long haul optical networks down to enterprise gear-optical networks, with the latter being typically implemented within one location e.g. in one office building.

The different types of optical networks can also be distinguished in terms of the physical environment in which equipment is located. For example, for enterprise gear-optical networks, the active equipment is typically located inside of air conditioned buildings, and therefore no particular extreme temperature condition compliance is required to implement such optical networks. For long haul and metro optical networks, which typically involve very complex and expensive active equipment, such drop equipment is typically located in telecommunications carriers central offices and points of presence and are subjected to a limited range of temperatures, which is sometimes referred to as requiring the add/drop equipment to be carrier class compliant. This temperature range is typically in the range of –5 to 55°C as required for Telcordia NEBS level 3.

However, in access optical networks the active equipment is typically located in an outside plant (OSP) situation, and thus potentially subjected to a wider temperature range than e.g. carrier class compliance requirements.

Currently, the only optical networks that can be implemented in scenarios where the required add/drop equipment is located in an OSP situation are Time Domain Multiplexing (TDM) based networks. So far, WDM based optical networks have not been deemed suitable for implementation in OSP situations, as currently available WDM equipment is not OSP compatible. However, it would be desirable to implement WDM based optical networks in

such an environment, to utilise the larger capacity in the optical domain in access optical networks. It would further be desirable if such an implementation could be achieved in a compact design for the hardware involved.

At least preferred embodiments of the present invention seek to provide a WDM module suitable for use in an OSP situation and facilitating a compact hardware design.

Summary of the invention

In accordance with a first aspect of the present invention, there is provided a WDM module comprising a plurality of WDM laser assemblies, each laser assembly comprising a laser source, wherein the WDM is arranged, in use, in a manner such that a controlled temperature environment is created around the laser sources of the laser assemblies, the controlled temperature environment being defined by a high and a low reference temperature value and having a temperature range equal to or smaller than an inherent operation temperature range of the laser sources, and in a manner such as to be capable of creating the controlled temperature environment around the laser sources while the WDM module is subjected to an outside temperature ambient having a temperature range larger than the inherent operation temperature range of the laser sources.

Preferably, the high reference temperature is 70°C or less.

The low reference temperature is preferably at least 0°C.

In one embodiment, the module comprises a housing, a chassis member located substantially inside the housing and adapted to function as a heat sink, a heat sink structure extending from the housing and in thermal communication with the chassis member, a thermoelectric (TE) device in thermal communication with the chassis member, at least one heat generating electrical component in thermal communication with the chassis member, and a control unit arranged, in use, to maintain a controlled temperature environment inside the housing utilising the heat sink structure, the TE device, and the heat generating electrical component and utilising the chassis member as a thermal communication medium.

The module may further comprise one or more highly thermally conductive members formed in or on the chassis member to facilitate the heatsink functionality of the chassis member.

Preferably, the module further comprises a local thermal environment structure located inside the housing and the TE device is in thermal communication with the chassis member and the local thermal environment structure, whereby, in use, a second stage controlled temperature environment is created substantially inside the local thermal environment structure, and wherein temperature variations in the second stage controlled temperature environment are smaller than temperature variations inside the housing.

The module may comprise at least one laser source disposed in a manner such that, in use, the source temperature of the laser source is substantially governed by the second stage controlled temperature environment.

In one embodiment, the laser source is a semiconductor laser source, and a junction of the laser source is located substantially inside the local thermal environment structure.

A laser driver associated with the laser source may be located substantially outside the local thermal environment structure, whereby the thermal environment around the laser driver is governed by the controlled temperature environment inside the housing.

In one embodiment, the module comprises a plurality of electrical components, and the control unit is further arranged, in use during start-up or re-start of the module, to sequentially switch on the electrical components based on operating temperature specifications and heat generating characteristics of the electrical components to facilitate creation of the controlled temperature environment.

The heat sink structure may comprise at least one heat pipe.

The heat pipe may have a working fluid characterised by a freezing temperature above -40°C, whereby a discontinuity in heat transfer to and from the heat sink structure is created for temperatures below the freezing temperature of the working fluid in the heat pipe for reducing heat loss from the inside of the housing.

The freezing temperature may be about zero °C.

In one embodiment, the chassis member comprises side walls formed around the peripheral region of a main body of the chassis member, and said side walls form at least a portion of housing side walls of the housing.

The housing is preferably adapted to function as an electro-magnetic induction (EMI) shield.

The module may further comprise biasing means for biasing the chassis member with respect to the heatsink structure.

In one embodiment, the module further comprises a first key member arranged, in use, to cooperate with a second key member formed on a casing member into which the module is inserted, to prevent the module from making contact with a backplane of the casing member when the module is inserted upside down into a slot of the casing member for which the module is not intended.

In accordance with a second aspect of the present invention, there is provided an optical network node incorporating a WDM module as defined in the first aspect.

In one embodiment, the network node is in the form of a regenerator node for a WDM network.

The network node may comprise an east network interface unit arranged, in use, to demultiplex an incoming WDM optical signal and to convert the incoming WDM optical signal into a plurality of electrical channel signals, and to convert and multiplex a plurality of electrical channel signals into an outgoing WDM optical signal, a west network interface unit arranged, in use, to demultiplex an incoming WDM optical signal and to convert the incoming WDM optical signal into a plurality of electrical channel signals, and to convert and multiplex a plurality of electrical channel signals into an outgoing WDM optical signal, and a regeneration unit disposed between the east and west interface units for regenerating the electrical channel signals utilising at least 2R regeneration.

The regenerator node may comprise two interconnected ones of the WDM modules, an east WDM module comprising the east interface unit, an east element of the regeneration unit, and a first electrical interface unit; and a west WDM module comprising a second electrical interface unit, a west element of the regeneration unit, and the west interface unit, wherein the east and west WDM modules are interconnected via the first and second electrical interface units.

In one embodiment, one or both of the east and west WDM modules further comprises a switching element for channel switching at the regenerator node.

Preferably, the regeneration unit is arranged for 3R regeneration.

In accordance with a third aspect of the present invention, there is provided a regenerator node for a WDM network, comprising an east network interface unit arranged, in use, to demultiplex an incoming WDM optical signal and convert the incoming WDM optical signal into a plurality of electrical channel signals, and to convert and multiplex a plurality of electrical channel signals into an outgoing WDM optical signal, a west interface unit arranged, in use, to demultiplex an incoming WDM optical signal and to covert the incoming WDM optical signal into a plurality of electrical channel signals, and to convert and multiplex a plurality of electrical channel signals into an outgoing WDM optical signal, and a regeneration unit disposed between the east and west interface units for regenerating the electrical channel signals utilising at least 2R regeneration.

In one embodiment, the regenerator node comprises an east WDM module comprising the east interface unit, an east element of the regeneration unit, and a first electrical interface unit; and a west WDM module comprising a second electrical interface unit, a west element of the regeneration unit, and the west interface unit, wherein the east and west WDM modules are interconnected via the first and second electrical interface units.

In one embodiment, one or both of the east and west WDM modules further comprises a switching element for channel switching at the regenerator node.

Preferably, the regeneration unit is arranged for 3R regeneration.

Brief description of the drawings

Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings.

Figure 1 shows a perspective view of a casing embodying the present invention.

Figure 2 shows a perspective view of the casing of Figure 1, with the top cover removed and components of a WDM add/drop multiplexer unit inserted.

Figure 3 is a perspective view of the casing of Figure 1 with components of a WDM add/drop multiplexer unit inserted.

Figure 4 is a perspective view of another casing embodying the present invention.

Figure 5 is a perspective view of another casing embodying the present invention.

Figure 6 is a perspective view of another casing embodying the present invention.

Figure 7 is a perspective view of a component of a WDM add/drop multiplexer unit, embodying the present invention.

Figure 8 is a perspective front view of the component shown in Figure 7.

Figure 9 is a schematic back view of another casing embodying the present invention.

Figure 10 is a perspective view of a chassis member embodying the present invention.

Figure 11 shows a perspective view of parts of a WDM multiplexer module embodying the present invention.

Figure 12 shows a perspective view of an assembled WDM multiplexer module embodying the present invention.

Figure 13 shows a perspective view of another chassis member embodying the present invention.

Figure 14 is a schematic diagram illustrating a WDM add/drop multiplexer unit embodying the present invention.

Figure 15 is a schematic diagram of a detail of Figure 14.

Figure 16 is a perspective view of a regenerator unit embodying the present invention.

Figure 17 is a schematic diagram illustrating the functional components of the regenerator unit of Figure 16.

Detailed description of the embodiments

The preferred embodiments described provide WDM module structures which are OSP compatible. In the following description various embodiments describe module structures and features which include add/drop functionality or relate to pass through regeneration only.

In Figure 1, a casing 10 embodying the present invention comprises top and bottom covers 12, 14 respectively. The casing 10 further comprises side walls 16, 18 respectively. Vent openings in the form of openings e.g. 20 in a mesh-type structure 22 forming the side walls e.g. 16 are incorporated for, in use, fluid communication between the inside 24 of the casing 10 and the surrounding ambient. The casing 10 further comprises intermediate walls 26, 28.

As can be seen more clearly in Figure 2, which shows the casing 10 without the top cover 12 (see Figure 1) and with components e.g. 30 of a WDM add/drop unit inserted, the casing 10 further comprises a backplane in the form of a mother board 32, for connection and interconnection of the inserted components e.g. 30, 34, and 36. The functionality of the various components will be described later with reference to Figures 9 and 10. It is noted that in the embodiment shown in Figure 2, the casing 10 is designed in a manner such that the heat sink openings 38 and 42, and the backplane 32 are mirrored with respect to a centreplane halfway along the width of the casing 10. This enables an optimal spacing between the set of fins 44, 46, and 48. At the same time, to facilitate that components 30 and 34, which, in end use, have different functionality and specifications, may initially undergo the same manufacturing steps and can be manufactured along the same production line up to a certain step, the components 30 and 34 are inserted with a "swapped" orientation. In other words, in terms of the individual chassis/housing of the components, 30 and 34, they are disposed upside down with respect to each other. To prevent inadvertent insertion of the wrong component, the electrical connections to the backplane 32 are keyed appropriately. Overall, the components 30, 34 are thus hot-swappable on-site.

In the example embodiment, and as shown in Figure 1, the casing member 10 comprises two key members in the form of two banded flaps e.g. 15 formed on the top and bottom covers 12, 14 respectively, and in a mirrored fashion in relation to the centreplane halfway along the width of the casing 10. In use, e.g. flap 15 will prevent component 30 (see Figure 2) from being fully inserted in any slot in the incorrect orientation. It will be appreciated by the person skilled in the art that the flap 15 is designed in the example embodiment to abud the set of fins 44 (see Figure 2) or 48 (see Figure 2), for preventing contact with the backplane 32 (see Figure 2) in those circumstances.

Furthermore, and referring now to Figure 2, the casing 10 further comprises secondary key members in the form of protrusions formed on sidewalls 26, 28 respectively and extending towards the components 30 and 34 respectively. The protrusions, which are hidden in Figure 2 as will be appreciated by the person skilled in the art, are arranged in a manner such that they cooperate with protrusions, in the example embodiment in the form of screws (not shown) screwed onto the respective components 30, 34 to prevent insertion of components 30, 34, would, into the position intended for the other component to an extent that they make contact

with the backplane 32. It will be appreciated by the person skilled in the art, that accordingly, in the example embodiment, the casing 10 is double-keyed to prevent wrong insertion of components 30, 34.

It is noted that in the example embodiment, the respective contacts (not shown) on the backplane 32 intended for the components 30, 34 are disposed in a manner such that their relative positioning on the backplane 32 is effectively an upside down and left/right swapped configuration, which further facilitates that components 30 and 34 may be manufactured along the same production line up to a certain step, as mentioned above. At the same time, wrong insertion of the individual components in the swapped orientation in the other component's spot is prevented, in the example embodiment, through the secondary key member as described above.

The casing 10 further comprises three heat sink openings 38, 40 and 42. The heat sink openings 38, 40, and 42 are each disposed in a manner such that heat sink structures in the form of sets of fins 44, 46, and 48 respectively extend therethrough to be exposed to the ambient outside of the casing 10. The sets of fins 44, 46, and 48 are part of the inserted components 30, e.g. 36, and 34 respectively, i.e. they are not mounted to or formed integrally with the casing 10. It will be appreciated by a person skilled in the art that accordingly, unlike in prior art designs, in the casing 10 embodying the present invention the provision of heat sinks in the form of e.g. fins has been separated from the casing 10 per se. Rather openings 38, 40 and 42 are provided through which heat sink structures of individual components inserted in the casing 10 can be received and exposed to the ambient outside the casing 10. It will be appreciated that this increases the flexibility concerning temperature control requirements of e.g. a WDM add/drop multiplexer unit mounted by way of the casing 10, as compared to prior art designs in which such heat sink structures are incorporated in the housing. In other words, if a temperature control requirement for an individual component changes, and thus an associated heat sink structure needs to be re-designed, this re-design does not require a re-design of the casing 10.

The casing 10 further comprises mounting brackets 50, 52 for mounting the casing 10 onto a rack structure (not shown).

Figure 3 shows the casing 10 including the top cover 12 and with the components of a WDM add/drop unit inserted, e.g. components 30, 36, and 34.

In an optional modification of the casing 10, shown in Figure 4, fans 41, 43 are mounted onto the backplane 32 in the space between the sets of fins 44, 46, and 48. The fans 41, 43 are disposed in a manner such that they generate an airflow substantially in the plane of the casing 10 and parallel to the fins. The embodiment shown in Figure 4 is suitable for situations where limited space is provided around the set of fins 44, 46, and 48 when the casing 10 is mounted onto a rack (not shown), to facilitate maintaining a controlled temperature environment of the WDM add/drop multiplexer unit. It will be appreciated by the person skilled in the art that, depending on requirements, only one or more than two fans may be provided in alternative embodiments.

In another embodiment shown in Figure 5, a casing 300 again comprises two heat sink openings 338, 342 for receiving heat sink structures 344, 348 of components 330, 334 of a WDM add/drop multiplexer unit. However, in this embodiment the casing 300 comprises a heat sink unit in the form of a set of fins 346 and heat pipes e.g. 347 externally mounted on a backplane 332 of the casing 300. Additional components, e.g. 336 of the WDM add/drop multiplexer unit, which are inserted into the casing 300, do not contain integral heat sink structures, but rather they are adapted to thermally connect to the set of fins 346 and the heat pipes e.g. 347, when inserted. The thermal connection is adapted to be releasable for replacement of such components, e.g. 336. Suitable implementations for achieving such releasable thermal connection include biasing mechanisms such as straps, levers, cams, or springs.

In the example embodiment shown in Figure 5, the material of the backplane 332 of the casing 300 and the material in an abutment portion of additional components e.g. 336, have thermal expansion co-efficients working in conjunction to determine the tolerances of the modules. In the example embodiment, a thermal mismatch was chosen such that thermal communication at the interface is of lower quality at low temperatures, and of better quality in normal or hotter temperature conditions. This allows local heat generated by components (not shown) to be used to maintain a high enough operating temperature at low ambient temperatures, which in turn can reduce the size of or make unnecessary additional heat sources for use at such low ambient temperature conditions.

The "hybrid" solution of combining heat sink openings e.g. 338 with a heat sink structure mounted onto the actual casing 300 can provide an alternative of design for best

overall thermal performance of the WDM add/drop multiplexer unit. Parameters to be considered in choosing the optimum design are expected to include the relationship between the space consumed by an individual component and the heat it generates, and the size-requirements of the backplane to provide the electrical interconnections between the components.

In yet another embodiment shown in Figure 6, a casing 450 again comprises two heat sink openings 488, 492 for receiving heat sink structures of components of a WDM add/drop multiplexer unit (not shown). In this embodiment, the backplane 482 of the casing 450 comprises a number of electrical connectors, e.g. 452, 454 and a series of four connectors 456.

In Figure 7, a component for insertion into the casing 450 (Figure 6) for electrical contact with one of the electrical connects 456 (Figure 6) in the form of a tributary interface module 500 is shown. Arrow 501 indicates the insertion direction for clarity. The module 500 has a corresponding electrical connector 502 for making electrical contact with one of the connectors 456 (Figure 6) when fully inserted into the casing 450 (Figure 6). When inserted, the module 500 makes thermal contact with the heat sink surface 449 (Figure 6) via a thermally conductive malleable pad portion 504 of a chassis member 506 of the module 500. It will be appreciated by the person skilled in the art that through use of the thermal pad portion 504, a desired thermal conductivity between the module 500 and the heat sink surface 449 (Figure 6) can be maintained over a large temperature range, despite potential mismatch in thermal expansion co-efficients of the material of the chassis 506 when compared with the material of the heat sink surface 449 (Figure 6). It will also be appreciated by the person skilled in the art that the malleable pad portion 504 can also accommodate mechanical hardware mismatch as a result of hardware manufacturing variation of the various hardware elements. The term "malleable" is intended to refer to the ability of the pad portion 504 to be capable of being deformed, preferably elastically, in order to establish thermal contact between the chassis member 506 and the heat sink surface 449 over a range of distances between the heat sink surface 449 and the chassis member 506 (in the region of the malleable pad portion 504 when the module 500 is fully inserted.

The module 500 further comprises a biasing mechanism 510 consisting of a spring loaded mounting member 512 (spring 514). The mounting member 512 comprises two teeth elements 516, 518 which engage into corresponding receiving slots on a cover (not shown) of

the casing 450 (Figure 6) when the module 500 is fully inserted. It will be appreciated by the person skilled in the art that accordingly the thermal (and electrical) connection between the module 500 and the heat sink surface 449 (Figure 6) is biased to accommodate relative dimensional changes caused e.g. by different thermal expansion of the various materials.

It will be appreciated by the person skilled in the art that other known biasing mechanisms may be used in different embodiments to maintain the desired thermal contact between the module 500 and the heat sink surface (Figure 6), such as straps, levers, or cams.

Figure 8 shows a front view of the module 500, showing more clearly details of the biasing mechanism 510. Arrow 503 indicates the insertion direction for clarity.

As illustrated in Figures 7 and 8, a heat pipe 508 is further embedded in the chassis member 506 of the module 500 utilising suitable grooves formed in the chassis 506. During operation, heat transfer from heat generating components within the module 500 (not shown), which are mounted onto the inside of the chassis 506 and cover members e.g. 507, is facilitated through the embedded heat pipe 508 and towards the heat sink surface (Figure 6) when the module 500 is inserted into the casing 450 (Figure 6). In the example embodiment, the heat pipe 508 comprises a copper heat pipe filled with water as a working fluid. In the example embodiment, water as the working fluid is suitable because it has a convenient freezing temperature of 0°C, which closes off the operation of the heat pipe 508 in cold conditions, i.e. when heat generated by components within the module 500 is advantageous to maintain a suitable operating temperature within the module 500. However, it will be appreciated by the person skilled in the art that other heat pipe designs can be selected in different embodiments, such as heat pipes made from different material and/or containing a different working fluid, or highly thermally conductive members in the form of diamond or graphite strips or rods.

It is noted that in the embodiments described above with reference to Figures 1 to 8, the design of the respective set of fins 44, 46, 48 and 344, 346, 348 is chosen such that the casings may be mounted horizontally or vertically. The fins are substantially planar and disposed parallel to the backwall of the casing. Furthermore, the heat pipes are formed longitudinally and without bends. It will be appreciated by the person skilled in the art, that accordingly, airflow between the fins is enabled with reduced, and preferably minimum restriction in either a horizontal or vertical mounting position.

Furthermore, the embodiments described above with reference to Figures 1 to 8 are dimensioned to fit into a 19 inch rack, and have a height of one rack unit. Alternatively the unit can be dimensioned to fit in a 23 inch rack. However, it will be appreciated by the person skilled in the art that the present invention is not limited to a particular overall size.

In yet another embodiment schematically shown in Figure 9, for a casing 400 which is to be vertically mounted, the casing 400 may comprise baffle structures 402, 404 disposed between sets of fins 406, 408 and 410. In this embodiment, the set of fins 406, 410 are formed integrally with components (not shown) inserted into the casing 400 and extending through heat sink openings 411, 412 of the casing 400. The fins 408 are mounted on a backplane 413 of the casing 400, and interconnect (releasably) to other components (not shown) inserted into the casing 400.

The baffle structures 402, 404 are disposed in a manner such that convection airflow from one set of fins is diverted from the other sets of fins as indicated by arrows 414. It will be appreciated by the person skilled in the art, that thus a successive heating of the convection air from the lowest set of fins 406 to the highest set of fins 410 can be reduced, and preferably be avoided.

Turning now to Figure 10, there is shown a chassis member 60 for carrying a plurality of circuit boards (not shown). The chassis member 60 is formed from a material having thermal characteristics suitable such that the chassis member 60 can, in use, function as a heat sink for heat generating electrical components (not shown) on the circuit boards (not shown) carried on the chassis member 60. In the example embodiment, the chassis member is formed form a zinc aluminium alloy.

Furthermore, the main body 62 of the chassis member 60 is contoured or shaped in a manner such that a distance between individual heat generating components (not shown) on the circuit boards (not shown) and regions of the main body facing the heat generating components is reduced compared to other components (not shown) on the circuit boards (not shown).

For example, the main body 62 comprises a raised portion 64 disposed in a manner such that, when a circuit board containing a particular heat generating electrical component is mounted on the chassis member 60, a distance between the top surface 66 of the raised portion 64 and the heat generating component (not shown) is reduced compared to other components (not shown) on the board (not shown).

The chassis member further comprises side wall structures 66, 68, 70 and 72 substantially around the peripheral region of the main body 62. The side wall portions 66, 68, 70 and 72 are formed integrally with and from the same material as the main body 62, and are adapted to function as at least portions of housing side walls of a housing structure (not shown) for the circuit boards (not shown) carried by the chassis member 60 and forming a WDM multiplexer module.

The chassis member 60 is further designed in a manner such that additional circuit boards (not shown) can be mounted to the "underside" 74 of the main body 62.

Turning now to Figure 11, there are shown parts of a WDM multiplexer module 80 comprising a chassis member 82 and a heat sink structure 84. The heat sink structure 84 comprises a plurality of fins e.g. 86 mounted on to three water based heat pipes 88, 90 and 92, extending through slots 94, 96, 98 respectively of a side wall portion 100 of the chassis member 82. The heat sink structure 84 further comprises four protective mounting rods e.g. 102 disposed in a manner such as to relief the heat pipes 88, 90, 92 from excessive load bearing as a result of a force being applied to one or more of the fins 86.

The heat pipes 88, 90, and 92 are mounted inside the WDM multiplexer module 80 and onto a main body 104 of the chassis member 82 by way of a thermally conducting mounting bracket 106. A TE device in the form of a thermoelectric conductor/cooler (TEC) 108 is located underneath the mounting bracket 106 and thermally connected to the main body 104 of the chassis member 82.

A local thermal environment structure including, in the example embodiment a laser housing 110 is mounted inside of the WDM multiplexer module 80 by way of a vertically mounted circuit board 112. Four semiconductor laser elements 114, 116, 118, and 120 are mounted in a manner such that their respective junction regions are located substantially inside or immediately adjacent to a thermally conductive base member 122 inserted in the laser housing 110, forming, in the example embodiment, the local thermal environment structure. A second TEC 124 is mounted on the main body 104 of the chassis member 82 and in thermal contact with base member 122 and thus with the laser structure 110.

It is noted that in the example embodiment illustrated in Figure 11, the laser drivers (not shown) associated with the lasers 114, 116, 118 and 120 will be located outside the laser housing 110, i.e. outside the local thermal environment created within the laser housing 110

(and conductive base member 122). The laser drivers (not shown) in the assembled module will be located on a circuit board (not shown) mounted on the main body 104 of the chassis member 82, i.e. their thermal environment will be governed by the "primary" thermal environment inside the module 80. It has been found that laser drivers rated to a temperature range that is compatible with the primary thermal environment are available for the design of the example embodiment.

Furthermore, it is noted that the TEC 124 electrically isolates the laser 114, 116, 118, and 120 from the chassis member 82. This has been found to improve the operation of the lasers, e.g. in terms of achievable bit rate.

In the following, operation of the heat control features of the WDM multiplexer module 80 to create a controlled temperature environment inside thereof will be described for an example setting of first and second stage temperature ranges.

For the purpose of this description, a maximum temperature range for an OSP situation is assumed to be from -40°C to +65°C.

In the high temperature extreme ambient situation of +65°C, the temperature inside the WDM multiplexer module 80 may be estimated to reach 85°C, due to heat generation from electronic devices (not shown) incorporated in the WDM multiplexer module 80. This is with only the heat sink structure comprising heat pipes 88, 90, 92 and the set of fins 84 considered at this stage.

In the example embodiment, the first stage temperature control is completed through utilising the first TEC 108 to reduce the temperature inside the WDM multiplexer module 80°C. With the TEC 108 being thermally connected to the thermally conducting chassis member 82, it will be appreciated that a relatively homogenous temperature profile can be achieved inside the WDM multiplexer module 80.

For the majority of components incorporated in the WDM multiplexer module 80, this maximum temperature of 80°C is tolerable. However, in the example embodiment shown in Figure 5, the lasers 114, 116, 118 and 120 are to be kept in a more tightly confined temperature range for specific reasons, including laser emission efficiency, wavelength stability, and accommodation of component variances between different lasers.

Accordingly, in a second stage temperature control, the 80°C environment inside the WDM multiplexer module 80 is locally reduced around the respective junctions of the lasers 114, 116, 118 and 120 by way of TEC 124 and via and the thermally conductive base element 122 located inside the laser housing 110. In the example embodiment, the temperature around the respective junctions of the lasers 114, 116, 118, and 120 is reduced from +80°C inside the WDM multiplexer module 80 to +50°C in and around the base element 122 for the high temperature extreme ambient situation.

At the low temperature extreme ambient situation of -40°C, it is assumed that the operation of heat generating components (not shown) inside the WDM multiplexer module 80 will again increase the temperature inside the WDM multiplexer module 80 by 20°C to -20°C. However, it is noted that due to variations in heating efficiencies with temperature and/or due to the fact that the water based heat pipes 88, 90, 92, which freeze below substantially 0°C, create a discontinuity in heat transfer to the set of fins 84, the temperature increase inside the WDM multiplexer module 80 as a result of heat generation from the heat generating components may be larger than 20°C. However, if for illustrative purposes a temperature increase to -20°C is assumed, the first stage temperature control in addition comprises utilising the TEC 108 to increase the temperature inside the WDM multiplexer module 80 by a further 20°C to 0°C.

Accordingly, the first stage temperature control has "buffered" the ambient temperature range of -40° to +65° to a temperature range of 0°C to +80°C inside the WDM multiplexer module 80. It is noted that while the high temperature end point is increased due to the internal heat generation, the overall range is reduced. It has been found that the WDM multiplexer module 80 can be designed in a manner such that this temperature range is tolerable for most of its components in an OSP situation.

Again, the lasers 114, 116, 118 and 120 do, however, require a more tightly confined temperature range, and thus the local thermal environment around the respective junctions of the lasers 114, 116, 118 and 120 at the low temperature end is "lifted" by a further 40°C to +40°C utilising TEC 124.

As a result, the second stage temperature environment range is from +40°C to +50°C, for an ambient temperature range of -40°C to +65°C. It has been found that this temperature range is satisfactory for construction of a WDM multiplexer module for use in an OSP situation.

Figure 12 shows an assembled WDM multiplexer module 130 embodying the present invention and suitable for use in an OSP situation. A housing structure comprising covers 132 and 134 is completed by side wall portions e.g. 136 of a chassis' member 138 of the WDM multiplexer module 130. On the front plane 140 of the WDM multiplexer module 130, suitable connections/connectors are provided, including to a trunk optical fibre network link 142 and a power connection 144. The housing structure is further designed in a manner such that it functions as an EMI shield for the internal components of the WDM multiplexer module 130.

Figure 13 shows another chassis member 550 for a WDM multiplexer module, embodying the present invention and suitable for use in an OSP situation. The chassis member 550 comprises embedded heat pipes 552, 554, 556 and 557a, b. Similar to the functioning of heat pipe 508 described above with reference to Figures 7 and 8, in use the heat pipes 552, 554 and 556 facilitate transfer of heat from heat generating components (not shown) towards a heat sink structure in the form of a set of heat fins 558 mounted directly to the heat pipes 552, 554 and 556 extending out from the main body of the chassis member 550. In the example embodiment, the chassis member 550 is made from an aluminium alloy, because it is machinable and light weight, thus facilitating mass manufacture and physical implementation requirements. In the example embodiment, to improve the thermal conductive properties of the chassis 550, the embedded heat pipes 552, 554, and 556 are utilised. Again, the surface e.g. upper surface 562 of the chassis member 550 is contoured to meet desired heat transfer requirements between the chassis member 550 and individual heat generating components (not shown) on a circuit board (not shown) mounted onto the chassis member 550.

In the example embodiment the heat pipes 552, 554, 556 and 557a,b are in the form of copper heat pipes filled with water as a working fluid, thus again utilising the convenient freezing temperature of 0°C to cut off heat transfer through the pipes 552, 554, 556 at low temperatures. However, it will be appreciated by the person skilled in the art that different heat pipe designs can be chosen in different embodiments of the present invention to meet desired requirements.

It will further be appreciated by the person skilled in the art, that the inventive concept of "embedded" heat pipes to improve heat transfer in a chassis member can be implemented in different ways without departing from the spirit or scope of that inventive concept. For example, in alternative embodiment heat pipes of any shape could be glued or otherwise

mounted to a surface of a chassis member, i.e. without provision of grooves. In yet another embodiment, holes could be drilled through the chassis member to accommodate heat pipes. In yet another embodiment, the chassis member could be formed from more than one part with channels formed in at least one part so that when the separate parts are brought together to form the chassis, conduits are formed which can contain a suitable working fluid.

In the following, some further features of a WDM multiplexer module embodying the present invention will be described for start-up or re-start scenarios at the low temperature end of an OSP situation. At the low temperature end of -40°C, it may be detrimental to power up all of the electrical components of the WDM multiplexer structure at once. It is assumed that in the start-up or re-start situation, all power was initially cut, i.e. the TECs are also inoperable.

Some of the components may either malfunction or even break down when operated at such low temperatures. Accordingly, in an embodiment of the present invention, a control unit is utilised to sequentially power up groups and/or individual ones of the internal electrical components, based on operating temperature specifications and heat generating characteristics of the electrical components. This (a) saves those components not suitable for power up from malfunction/breakdown, and (b) forms the first step of a first stage temperature control similar to the one described above with reference to Figure 5, i.e. it facilitates a temperature increase inside the WDM multiplexer module due to heat generation from the powered up components. When or as the temperature is raised internally due to the heat generation, remaining components are powered up in a then increased temperature environment designed to be safe for those components.

In the following, the functionality of a WDM add/drop multiplexer structure for use at a node in an optical Access network embodying the present invention will be described with reference to Figures 14 and 15.

Figure 14 shows a schematic diagram of a network node structure 200 for use in an Access WDM network embodying the present invention. The node structure 200 comprises two network interface modules 212, 214, an electrical connection motherboard 216 and a plurality of tributary interface modules e.g. 218. The network interface modules 212, 214, the electrical connection motherboard 216 and the plurality of tributary interface modules e.g. 218 compare with items 30, 34, 32, and 36 respectively in Figure 2.

In the example embodiment, the network interface modules 212, 214 are designed in the same fashion as the WDM multiplexer modules described above with reference to Figures 10 to 13. Therefore, in the example embodiment, they are OSP compatible. Similarly, the tributary interface modules e.g. 218 are designed in the same fashion as the tributary interface module described above with reference to Figures 7 and 8, and are, in the example embodiment, OSP compatible.

Returning to Figure 14, the network interface modules 212, 214 are connected to an optical network east trunk 220 and an optical network west trunk 222 respectively, of a WDM optical network (not shown) to which the network node structure 210 is connected in-line. The WDM optical network may for example be arranged as a WDM optical ring network, or as a WDM linear optical network.

Each of the network interface modules 212, 214 comprises the following components:

- a passive CWDM component 224, in the exemplary embodiment a 8 wavelength component;

- an electrical switch component, in the exemplary embodiment a 16 x 16 switch 226;

- a microprocessor 228;

- a plurality of receiver trunk interface cards e.g. 230; and

- a plurality of transmitter trunk interface cards e.g. 232, and

- a plurality of electrical regeneration unit e.g. 240 associated with each receiver trunk interface card e.g. 230.

Each regeneration unit e.g. 240 performs 3R regeneration on the electrical channels signal converted from a corresponding optical WDM channel signal received at the respective receiver trunk interface card e.g. 230. Accordingly, the network node structure 200 can provide signal regeneration capability for each channel signal combined with an electrical switching capability for add/drop functionality, i.e. avoiding high optical losses incurred in optical add/drop multiplexers (OADMs).

Details of the receiver trunk interface cards e.g. 230 and regeneration unit e.g. 240 of the exemplary embodiment will now be described with reference to Figure 15.

In Figure 15, the regeneration component 240 comprises a linear optical receiver 241 of the receiver trunk interface card 230. The linear optical receiver 241 comprises a transimpendence amplifier (not shown) i.e. 1R regeneration is performed on the electrical receiver signal within the linear optical receiver 241.

The regeneration unit 240 further comprises an AC coupler 256 and a binary detector component 258 formed on the receiver trunk interface card 230. Together the AC coupler 256 and the binary detector 258 form a 2R regeneration section 260 of the regeneration unit 240.

The regeneration unit 240 further comprises a programmable phase lock loop (PLL) 250 tapped to an electrical input line 252 and connected to a flip flop 254. The programmable PLL 250 and the flip flop 254 form a programmable clock data recovery (CDR) section 255 of the regeneration unit 240.

It will be appreciated by a person skilled in the art that at the output 262 of the programmable CDR section 255 the electrical receiver signal (converted from the received optical CWDM channel signal over optical fibre input 264) is thus 3R regenerated. It is noted that in the example shown in Figure 15, a 2R bypass connection 266 is provided, to bypass the programmable CDR section 255 if desired.

Returning now to Figure 14, each of the tributary interface modules e.g. 218 comprises a tributary transceiver interface card 234 and an electrical performance monitoring unit 236. A 3R regeneration unit (not shown) similar to the one described in relation to the receiver trunk interface cards e.g. 230 with reference to Figure 11 is provided. Accordingly, 3R regeneration is conducted on each received electrical signal converted from received optical input signals prior to the 16 x 16 switch 226.

As can be seen from the connectivity provided through the electrical motherboard 216, each of the electrical switches 226 facilitates that any trunk interface card e.g. 230, 232 or tributary interface card e.g. 218 can be connected to any one or more trunk interface card e.g. 230, 232, or tributary interface card e.g. 218. Accordingly, e.g. each wavelength channel signal received at the western network interface module 214, e.g. at receiver trunk interface card 238 can be dropped at the network node associated with the network node structure 200 via any one of the tributary interface modules e.g. 218, and/or can be through connected into the optical network trunk east 220 via the east network interface module 212.

Furthermore, it will also be appreciated by the person skilled in the art that the network node structure 200 is west-east/east-west traffic transparent. Also, due to the utilisation of network interface modules 212, 214 which each incorporate a 16 x 16 switch 226, a redundant switch is readily provided for the purpose of protecting the tributary interface cards e.g. 218 from a single point of failure. The tributary interface cards e.g. 218 are capable of selecting to transmit a signal to either (or both) network interface modules 212, 214 and the associated switches e.g 226. The function of the switches e.g. 226 is to select the wavelength and direction that the optical signal received from the tributary interface cards e.g. 218 will be transmitted on and into the optical network.

One of the advantages of the network structure 200 (Figure 14) is that the electronic switches support broadcast and multicast transmissions of the same signal over multiple wavelengths. This can have useful applications in entertainment video or data casting implementation. Many optical add/drop solutions do not support this feature, instead, they only support logical point-point connections since the signal is dropped at the destination node and does not continue to the next node.

The embodiments described above concern implementations of the present invention in the context of a WDM add/drop multiplexer unit. However, it will be appreciated that the present invention is not limited to that particular form of WDM equipment. For example, in another embodiment shown in Figure 16, the present invention is implemented for a WDM optical regenerator 1200. The regenerator 1200 comprises a casing 1202 having two heat sink openings 1238, 1242 for receiving heat sink structures 1244, 1248 of two WDM regenerator components 1230, 1234 of the WDM regenerator 1200. In this embodiment, the casing 1202 comprises a heat sink unit in the form of a set of fins 1246 and heat pipes (not shown) carrying the set of fins 1246, externally mounted on a backplane 1232 of the casing 1202.

Figure 17 shows a schematic diagram illustrating the functional components of the generator 1200 of Figure 12. The regenerator 1200 comprises two network interface modules 1312, 1314, and an electrical connection motherboard 1316, mounted on the backplane 1232 (Figure 16) of the casing 1202 (Figure 16). The network interface modules 1312, 1314 are connected to an optical network east truck 1320, and an optical network west trunk 1222, respectively, of a WDM optical network (not shown) to which the regenerator 1200 is

connected in-line. The WDM optical network may, for example, be arranged as a WDM optical ring network, or as a WDM linear optical network.

In the example embodiment, the network interface modules 1312, 1314 are designed in the same fashion as the WDM multiplexer modules described above with reference to Figures 10 to 13. Therefore, in the example embodiment, they are OSP compatible.

Each of the network interface modules 1312, 1314 comprising the following components:

- a passive CWDM component 1324, in the exemplary embodiment a 8 wavelength component for 4 bi-directional CWDM channels;

- a microprocessor 1328;

- a plurality of receiver trunk interface cards e.g. 1330;

- a plurality of transmitter trunk interface cards e.g. 1332; and

- a plurality of electrical regeneration units e.g. 1340 associated with each receiver trunk interface card e.g. 1330.

- optionally, an electrical switch component, in the exemplary embodiment a 16 x 16 switch 1326;

Each regeneration unit e.g. 1340 performs 3R regeneration on the electrical channel signals converted from a corresponding optical WDM channel signal received at the respective receiver trunk interface card e.g. 1330. Accordingly, the regenerator 1200 can provide signal regeneration capability for each channel signal, potentially combined with an electrical switching capability that can enable loop-back functionality for remote diagnostics or for switching between different WDM channels at the regenerator 1200, if required.

The receiver trunk interface cards e.g. 1330 and regeneration unit e.g. 1340 of the exemplary embodiment are substantially identical to the corresponding components in the previous embodiment as described with reference to Figure 15.It will be appreciated by the person skilled in the art that in the generator 1200, 4 bi-directional CWDM channels can be bi-directionally regenerated.

It will be appreciated by the person skilled in the art that numerous modifications and/or variations may be made to the present invention as shown in the specific embodiments without

departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

In the claims that follow and in the summary of the invention, except where the context requires otherwise due to express language or necessary implication the word "comprising" is used in the sense of "including", i.e. the features specified may be associated with further features in various embodiments of the invention.